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(54) **BATTERY PACK LEAK DETECTION ASSEMBLY AND METHOD**

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(51) **Int. Cl.**

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B60L 11/18	(2006.01)
H01M 10/48	(2006.01)
H01M 10/6565	(2014.01)

(52) **U.S. Cl.**

CPC ***G01M 3/002*** (2013.01); ***B60L 11/187*** (2013.01); ***H01M 10/486*** (2013.01); *H01M 10/6565* (2015.04)

(58) **Field of Classification Search**

USPC 374/4

See application file for complete search history.

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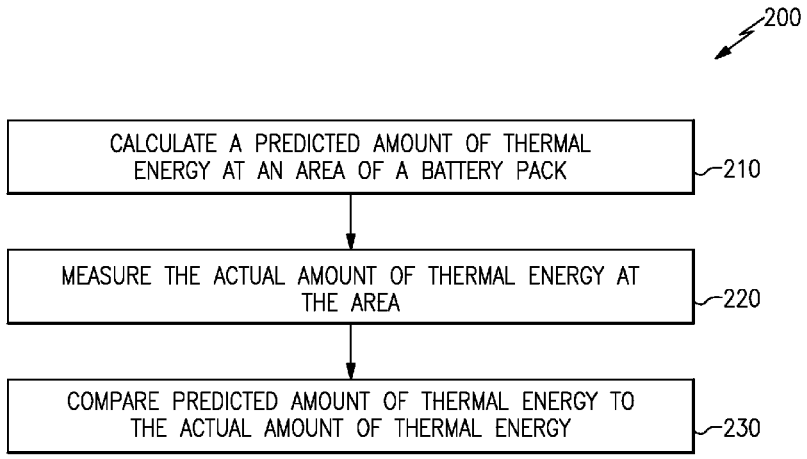
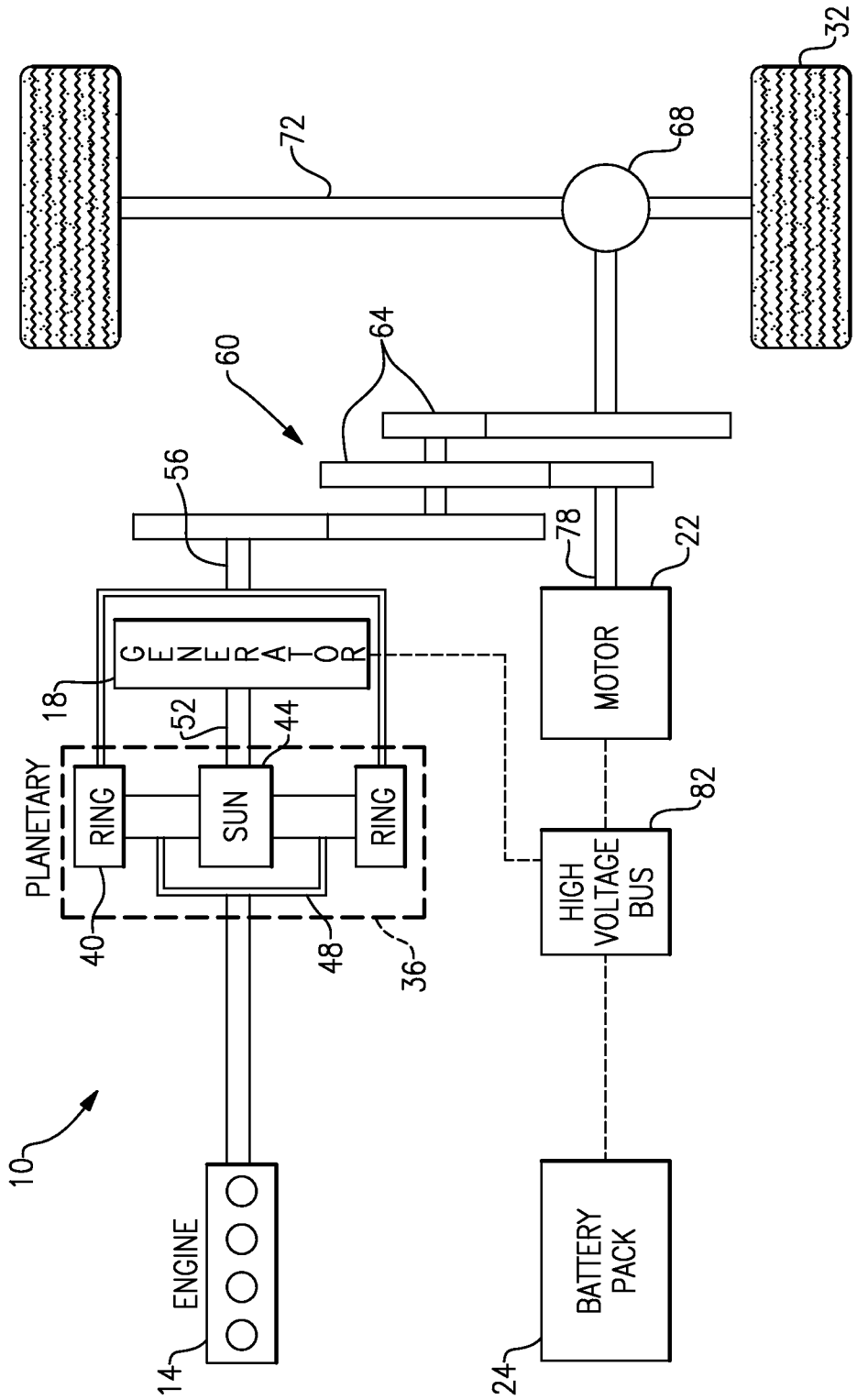
(57) **ABSTRACT**

A method of detecting a leak in a battery pack according to an exemplary aspect of the present disclosure includes, among other things, calculating a predicted amount of thermal energy at a position, measuring an actual amount of thermal energy at the position, and comparing the predicted amount to the actual amount to identify if a battery pack is leaking.

19 Claims, 3 Drawing Sheets




32
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GENERATOR
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44
PLANETARY
RING
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HIGH VOLTAGE BUS
40
48
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ENGINE
14
BATTERY PACK
24

FIG. 1

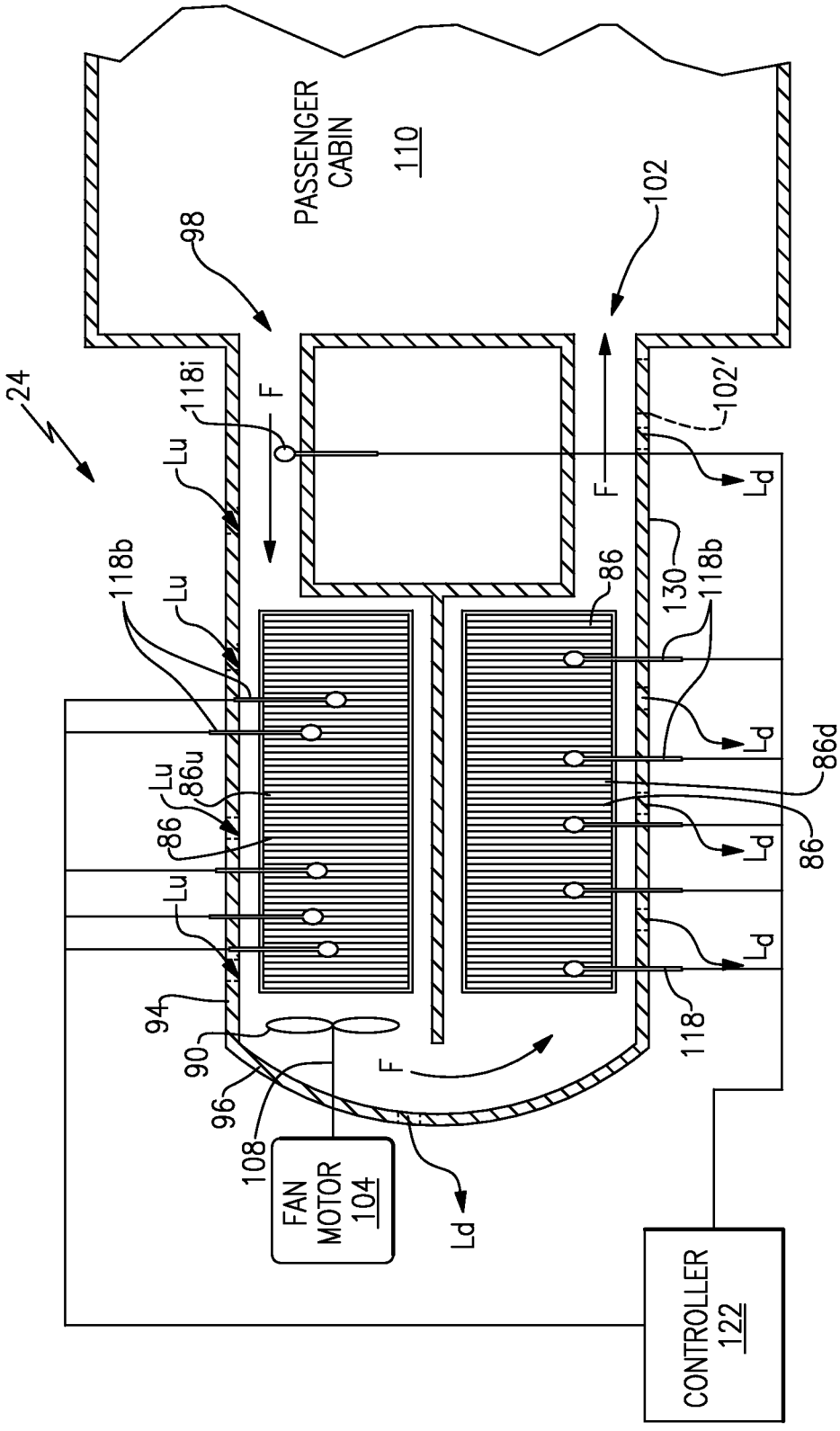
PASSENGER CABIN
110
98
102
102'
24
118i
F
Lu
Ld
118b
86
130
86u
86d
94
90
96
108
FAN MOTOR 104
118
CONTROLLER 122

FIG.2

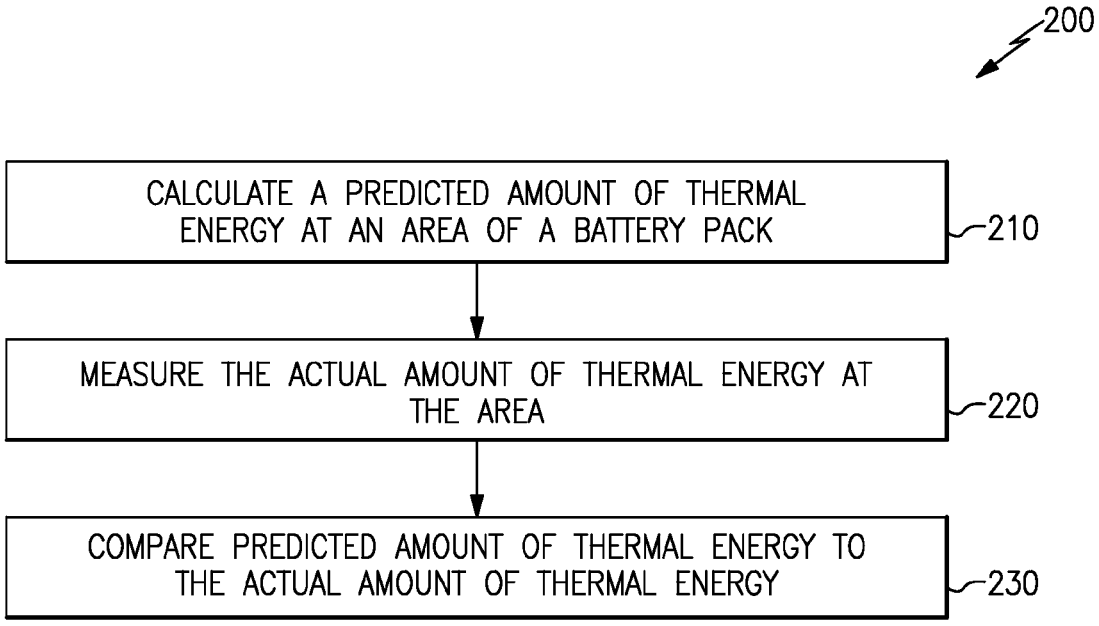
200
CALCULATE A PREDICTED AMOUNT OF THERMAL ENERGY AT AN AREA OF A BATTERY PACK
210
MEASURE THE ACTUAL AMOUNT OF THERMAL ENERGY AT THE AREA
220
COMPARE PREDICTED AMOUNT OF THERMAL ENERGY TO THE ACTUAL AMOUNT OF THERMAL ENERGY
230

FIG.3

BATTERY PACK LEAK DETECTION ASSEMBLY AND METHOD

BACKGROUND

This disclosure relates generally to a battery pack for an electric vehicle and, more particularly, to detecting undesirable thermal energy leaks and undesirable fluid leaks in the battery pack.

Generally, electric vehicles differ from conventional motor vehicles because electric vehicles are selectively driven using one or more battery-powered electric machines. Conventional motor vehicles, by contrast, rely exclusively on an internal combustion engine to drive the vehicle. Electric vehicles may use electric machines instead of, or in addition to, the internal combustion engine.

Example electric vehicles include hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs). Electric vehicles are typically equipped with a battery pack containing battery cells that store electrical power for powering the electric machine. The batteries may be charged prior to use, and recharged during drive by a regeneration brake or engine.

Extended exposure to significant thermal energy levels can shorten the useful life of a battery pack. Typically, the battery pack is thus thermally insulated from the surrounding environment. Further, a fan is used to move air through the battery pack. The moving air regulates thermal energy levels. The fan typically draws climate controlled air into the battery pack from a cabin of the vehicle. This air moves through the battery pack and exits to the cabin, the exterior of the vehicle, or trunk, etc. or combined of them.

A leak in the battery pack permits undesirable levels of fluid, thermal energy or both to communicate between an interior and an exterior of the battery pack. Insulation breakage during battery pack installation, customized vehicle work, etc. can cause leaks in the battery pack. Leaks lead to increased operating time for the fan, increased vehicle cabin temperatures, increased battery temperatures, reduced vehicle performance, etc. Technicians can undesirably devote considerable time to diagnosing and locating leaks.

SUMMARY

A method of detecting a leak in a battery pack according to an exemplary aspect of the present disclosure includes, among other things, calculating a predicted amount of thermal energy at a position, measuring an actual amount of thermal energy at the position, and comparing the predicted amount to the actual amount to identify if a battery pack is leaking.

In a further non-limiting embodiment of the foregoing method of detecting a leak in a battery pack, the method includes moving a fluid through the battery pack using a fluid movement device. The fluid enters the battery pack at an inlet and exits the battery pack at an outlet. The fluid movement device is positioned downstream from the inlet and upstream from the outlet relative to a direction of flow through the battery pack.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the leaking comprises movement of fluid to the battery pack through areas other than the inlet, movement of fluid from the battery pack through areas other than the outlet, or both. The leak, in some examples, is a thermal leak through the insulation layer. Fluid may or may not move through the leak.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the fluid movement device is a fan.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the method comprises measuring thermal energy of fluid entering through the inlet to provide an inlet fluid amount of thermal energy, and comparing the inlet fluid amount to the predicted amount to identify a location of the leaking.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the method includes calculating that the leak is between the inlet and the fluid movement device if the inlet fluid amount of thermal energy is greater than the actual amount of thermal energy at the position.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the position is at a battery cell of the battery pack.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the position is within the battery pack.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the method includes identifying a leak when the actual amount is greater than the predicted amount by at least an established threshold value, for example, three degrees Celsius.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the method includes identifying a leak when the predicted amount is greater than the actual amount by at least an established threshold value, for example, three degrees Celsius.

In a further non-limiting embodiment of any of the foregoing methods of detecting a leak in a battery pack, the method includes measuring the actual amount of thermal energy using a sensor positioned at or adjacent to battery cell of the battery pack.

A leak detection assembly for a battery pack according to an exemplary aspect of the present invention includes, among other things, a sensor to determine an actual amount of thermal energy at an position, and a controller to calculate a predicted amount of thermal energy at the position, and to indicate that a battery pack includes a leak based on a comparison of the predicted amount to the actual amount.

In a further non-limiting embodiment of the foregoing leak detection assembly, the assembly includes a fluid movement device to move fluid from an inlet of the battery pack to an outlet of the battery pack.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the fluid movement device comprises a fan.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the leak comprises movement of fluid to the battery pack through areas other than the inlet, movement of fluid from the battery pack through areas other than the outlet, or both. The leak may also comprise a thermal leak or movement of thermal energy (and no fluid) from the battery pack through the leak.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the assembly includes an inlet sensor to measure an amount of thermal energy in fluid entering the battery pack through the inlet, wherein the controller is configured to compare the inlet fluid amount to the predicted amount to identify a location of the leaking.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the controller indicates a leak when the predicted amount is greater than the actual amount by at least an established threshold value, for example, three degrees Celsius.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the controller indicates a leak when the actual amount is greater than the predicted amount by at least an established threshold value, for example, three degrees Celsius.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the position is within the battery pack.

In a further non-limiting embodiment of any of the foregoing leak detection assemblies, the position is at or adjacent to a battery cell of the battery pack.

DESCRIPTION OF THE FIGURES

The various features and advantages of the disclosed examples will become apparent to those skilled in the art from the detailed description. The figures that accompany the detailed description can be briefly described as follows:

FIG. **1** illustrates a schematic view of an example electric vehicle powertrain.

FIG. **2** illustrates a schematic view of an example battery pack used within the electric vehicle powertrain of FIG. **1**.

FIG. **3** illustrates the flow of an example method used to identify leaks within the battery pack of FIG. **2**.

DETAILED DESCRIPTION

FIG. **1** schematically illustrates a powertrain **10** for an electric vehicle. Although depicted as a hybrid electric vehicle (HEV), it should be understood that the concepts described herein are not limited to HEVs and could extend to other electrified vehicles, including but not limited to, plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

In one embodiment, the powertrain **10** is a powersplit powertrain system that employs a first drive system and a second drive system. The first drive system includes a combination of an engine **14** and a generator **18** (i.e., a first electric machine). The second drive system includes at least a motor **22** (i.e., a second electric machine), the generator **18**, and a battery pack **24**. In this example, the second drive system is considered an electric drive system of the powertrain **10**. The first and second drive systems generate torque to drive one or more sets of vehicle drive wheels **32** of the electric vehicle.

The engine **14**, which is an internal combustion engine in this example, and the generator **18** may be connected through a power transfer unit **36**, such as a planetary gear set. Of course, other types of power transfer units, including other gear sets and transmissions, may be used to connect the engine **14** to the generator **18**. In one non-limiting embodiment, the power transfer unit **36** is a planetary gear set that includes a ring gear **40**, a sun gear **44**, and a carrier assembly **48**.

The generator **18** may be driven by engine **14** through the power transfer unit **36** to convert kinetic energy to electrical energy. The generator **18** can alternatively function as a motor to convert electrical energy into kinetic energy, thereby outputting torque to a shaft **52** connected to the power transfer unit **36**. Because the generator **18** is operatively connected to the engine **14**, the speed of the engine **14** can be controlled by the generator **18**.

The ring gear **40** of the power transfer unit **36** may be connected to a shaft **56**, which is connected to vehicle drive wheels **32** through a second power transfer unit **60**. The second power transfer unit **60** may include a gear set having a plurality of gears **64**. Other power transfer units may also be suitable. The gears **64** transfer torque from the engine **14** to a differential **68** to ultimately provide traction to the vehicle drive wheels **32**. The differential **68** may include a plurality of gears that enable the transfer of torque to the vehicle drive wheels **32**. The second power transfer unit **60** is mechanically coupled to an axle **72** through the differential **68** to distribute torque to the vehicle drive wheels **32**.

The motor **22** (i.e., the second electric machine) can also be employed to drive the vehicle drive wheels **32** by outputting torque to a shaft **78** that is also connected to the second power transfer unit **60**. In one embodiment, the motor **22** and the generator **18** cooperate as part of a regenerative braking system in which both the motor **22** and the generator **18** can be employed as motors to output torque. For example, the motor **22** and the generator **18** can each output electrical power the battery pack **24** through a high voltage bus **82**.

The battery pack **24** may be a high voltage battery that is capable of outputting electrical power to operate the motor **22** and the generator **18**. Other types of energy storage devices and/or output devices can also be used with the electric vehicle.

Referring now to FIG. **2**, the example battery pack **24** includes a plurality of individual battery cells **86** and a fan **90**. A battery pack housing **94** holds the battery cells **86** and the fan **90**. The battery pack housing **94** includes an insulative layer **96** to thermally insulate the battery pack **24**. The battery pack housing **94** can include other layers in addition to the insulative layer **96**.

The battery pack **24** includes a flowpath F extending from an inlet **98** to an outlet **102**. The battery cells **86** are positioned within the flowpath F. The fan **90** moves a fluid along the flowpath F from the inlet **98** to the outlet **102**. The fluid, in this example, is drawn from a passenger cabin **110** of the vehicle. The fluid moves from the outlet **102** back to the passenger cabin **110**.

In another example, the fluid moves from the outlet **102** to an area outside of the passenger cabin **110**, such as through an outlet **102'**. The fluid may move through the outlet **102'** instead of, or in addition to, moving through the outlet **102**.

The fan **90** is a type of fluid movement device. A fan motor **104** drives a shaft **108** that extends through the battery pack housing **94** to drive the fan **90**. The fan **90** is downstream from the inlet **98** and upstream from the outlet **102** relative to a general direction of flow along the flowpath F.

Some of the battery cells **86*u*** are positioned upstream from the fan **90** relative to a general direction of flow through the battery pack **24**. Other battery cells **86*d*** are positioned downstream from the fan **90** relative to the general direction of flow through the battery pack **24**.

Fluid moving along the flowpath moves across the battery cells **86**, which regulates the amounts of thermal energy in the battery cells **86**. In one example, fluid moves across the battery cells **86** to carry thermal energy away from the battery cells **86** and thereby lower a temperature of the battery cells **86**.

A plurality of thermal energy sensors **118** extend into the battery pack **24**. The sensors **118** collect thermal energy measurements from the battery pack **24**. The temperatures of the battery cells **86** within the battery pack **24** can range, for example, from −40 to 65 degrees Celsius, so the example

thermal energy sensors **118** are able to collect thermal energy measurements across at least this range.

In this example, some of the sensors **118***b* measure thermal energy amounts at ten separate locations that are within or near the groups of battery cells **86**. Five of the sensors **118***b* measure thermal energy at locations within the battery cells **86***u* that are upstream from the fan **90**. Five of the sensors **118***b* measure thermal energy amounts at locations within the battery cells **86***d* that are downstream from the fan **90**.

The readings from the sensors **118***b* reveal an actual amount of thermal energy at the locations. When the location is on (or sufficiently close to) one or more of the battery cells **86**, the readings from the sensors **118***b* represent an actual amount of thermal energy in those battery cells **86**.

Another of the sensors **118***i* measures an amount of thermal energy in the flow moving through the inlet **98**.

The sensors **118** are operably coupled to a controller **122** that collects the thermal energy readings from the sensors **118**.

Leaks can develop in the battery pack housing **94**. Leaks permit undesirable fluids, thermal energy, or both to move to or from the battery pack housing **94** at a location other than the inlet **98** and the outlet **102**.

The example battery pack **24** includes upstream leaks L_u that are upstream relative to the fan **90**. The upstream leaks L_u permit fluid or thermal energy outside the passenger cabin **110** to be drawn into the battery pack **24**, rather than fluid from the passenger cabin **110**.

The example battery pack **24** includes downstream leaks L_d that are downstream relative to the fan **90**. The downstream leaks L_d permit fluid or thermal energy within the battery pack **24** to escape from the battery pack **24** though a location other than the outlet **102**.

The upstream leaks L_u offer little resistance to fluid moving into the battery pack **24** compared to the relatively restricted flow from the passenger cabin **110**. The upstream leaks L_u can cause an amount of thermal energy in the battery cells **86** to increase or decrease depending on the ambient temperature of the battery pack **24** and the temperature of the fluid in the environment that enters the battery pack **24** via the upstream leaks L_u Fluid entering the battery pack **24** via the upstream leaks L_u has not been conditioned within the passenger cabin **110**.

In hot weather, for example, fluid moving into the battery pack **24** through the upstream leaks L_u could be very hot, which could cause some areas of the battery pack **24** near the upstream leaks L_u to heat up disproportionately to other areas. In cold weather, fluid moving into the battery pack **24** through the upstream leaks L_u could be very cold and cause some areas of the battery pack **24** near the downstream leaks L_d to cool disproportionately to other areas.

In an example embodiment of this disclosure, the controller **122** identifies that the battery pack **24** has leaks using, in part, readings from the sensors **118***b*, the sensor **118***i*, or both. If the controller **122** calculates that the battery pack **24** includes leaks, a technician can then inspect and repair the battery pack **24**. If a leak is found, the leak can be repaired to ensure that flow across the battery cells **86** is not influenced by the leak.

Referring now to FIG. **3** with continuing reference to FIG. **2**, to detect leaks, an example method **200**, at a step **210**, calculates a predicted amount of thermal energy at a position within the battery pack **24**. The method **200** also measures, at a step **220**, the actual amount of thermal energy at the position. The method **200** may use, for example, readings of thermal energy from the sensors **118***b* to measure the actual amount of thermal energy at the position.

At a step **230**, the method **200** compares the predicted amount of thermal energy to the actual amount of thermal energy. The method **200** detects leaks in the battery pack **24** based on this comparison.

The method **200** may rely, in part, on a battery pack temperature estimation equation, which has been reproduced below as equation (1).

$$\frac{d}{dt}[C_{p,cell} \cdot T_{cell}] + \frac{d}{dt}[E_{cell}(SOC)] = h \cdot (T_{air} - T_{cell}) + V_{cell} \cdot I \quad \text{Equation (1)}$$

In this example, $C_{p,\,cell}$ represents the heat capacity of the battery cell **86** and harnesses associated with the battery cell **86**. E_{cell} represents the electrical energy in the battery cell **86**. T_{air} represents a temperature of the air into the battery pack **118***i*, T_{cell} represents a temperature of a battery cell **86**, and h represents the heat transfer coefficient. V_{cell} represents the terminal voltage of the cell **86**. I represents the pack current. In the current sign convention, a positive value is for a charge current. Thus, equation (1), in this example, sets the thermal and electrical energy increase in the battery pack **24** to be equal to both the heat transfer into battery pack **24** and the power generated by the battery pack **24**.

To calculate the estimated temperature at a position within the battery pack **24**, such as a selected battery cell **86**, the method **200** may determine heat transfer out (HT_{out}) of battery cell **86** using equation (2), which has been reproduced below:

$$HT_{out}=(h_0+\text{fan_air_flow_rate}\times h_{fan_on})\times(T_{air}-T_{cell}) \quad \text{Equation (2)}$$

The heat transfer coefficient h_0 and the fan on heat transfer coefficient h_{fan_on} are constants and can be obtained with fan off and fan on battery pack temperature test data. A person having skill in this art and the benefit of this disclosure would be able to obtain these coefficients.

The heat generated by the battery cell is, essentially, the electrical energy consumed. The heat generated by the battery cell is represented by BP_{HG} and can be calculated using equation (3), which has been reproduced below:

$$BP_{HG}=I^2\times R_{cell} \quad \text{Equation (3)}$$

In Equation (3), I is the electrical current through the battery pack **24** and R_{cell} is the total electrical resistance (both cell and harnesses) of the battery cell **86**.

The battery cell temperature T_{cell} can then be estimated using Equation (4), which has been reproduced below:

$$BP_{HG}-HT_{out}=C_{p,cell}\times(d(T_{cell})/dt) \quad \text{Equation (4)}$$

Solving the above equations provides T_{cell}, which is an estimate of the thermal energy in the battery cell **86** associated with the position. To compensate the delay of sensor measured temperature, filter(s) and/or pure delay can be used to simulate the real sensor reading. In the example method, if temperature of the battery cell **86** (measured by one or more of the sensors **118***b*) is significantly different than estimated temperature of the battery cell T_{cell}, the battery pack **24** is considered to have a leak.

In some examples, the predicted amount of thermal energy and the actual amount of thermal energy are represented as temperatures measured in degrees Celsius. If the predicted amount equals or exceeds an established threshold value, the method **200** indicates that the battery pack **24** is leaking. For example, if the established threshold value is an absolute value of three degrees Celsius, and the predicted

amount is three or more degrees Celsius greater than the measured amount, the method **200** indicates that the battery pack **24** is leaking. In addition, if the predicted amount is three or more degrees Celsius less than the actual amount of thermal energy, the method **200** indicates that the battery pack **24** is not leaking. In this example, the threshold value is calibratable and can be adjusted based on specific requirements, such as battery pack **24** size.

In one example, the battery pack **24** is only to be considered leaking if, in addition to the predicted amount varying three or more degrees from the actual amount, a fault associated with the sensor **118***b* has not also been detected within a certain timeframe, say this drive cycle. An example fault is a sensor **118***b* that has failed and does not provide a reading, for example.

A further example embodiment of this disclosure can determine the general positions of leaks within the battery pack **24** to assist the technician inspecting the battery pack **24**. For example, in hot weather, the air outside the battery pack **24** is relatively hot, and the thermal energy levels of the battery cells **86** upstream from the leak will be higher than those downstream from the leak. The controller **122** calculates the location within the battery pack **24** where the temperature transitions from a lower to a higher temperature. This location is then flagged as the likely location of the leak.

The technician begins a search for the leak in the flagged location, which can help reduce inspection time. The controller **122** uses information collected by the sensors **118***b*, the sensor **118***i*, or both to calculate the location of the temperature transition.

Identifying the general location of the leak could involve calculating whether the leak is on, for example, the driver or passenger side of the battery pack **24**. Identifying the general location of the leak could be more specific, such as a specific battery cell **86** that is closest to the leak.

The controller **122** can identify that the leak is an upstream leak L_u, in one example, when the temperature of fluid moving out of the outlet **102** into the passenger cabin **110** is elevated. This may be due to the flow from the passenger cabin **110** mixing with the hotter fluid entering the flowpath F through the upstream leak L_u The fluid moving out of the outlet will cause the temperature measured by the inlet sensor **118***i* to be higher than the temperature measured by the sensors **118***b* upstream from the upstream leak L_u.

In one example, the controller **122** can identify that the leak is a downstream leak L_d. Fluid can move out of the battery pack **24** through the downstream leak L_d instead of through the outlet **102**. The fluid moves through the path of the downstream leak L_d rather than through the outlet **102** due to less air resistance along the path provided by the downstream leak L_d versus the resistance associated with the outlet **102**. The resistance of the outlet **102** is typically higher than the resistance at the location of the leak due to a pipe **130** and the structure of the outlet **102** providing a relatively open path to the passenger cabin **110**.

The controller **122** calculates an area having the leak recognizing that areas of the battery pack **24** downstream from the leak will have elevated temperatures relative to areas of the battery pack **24** upstream from the leak. The relative elevated temperatures are due to less air movement across the areas downstream from the leak.

In some examples, if the battery pack **24** includes leaks both upstream and downstream from the fan **90**, fluid moving through the leak paths will be cycled out of the battery pack **24**. The battery pack **24** will then use flow from the area around the pack instead of passenger cabin **110** and the battery pack **24** will be heated very quickly. Fan speed will have little impact on the ability of the fan **90** to reduce the temperature of the battery cells **86** within the battery pack **24**.

Although the different non-limiting embodiments are illustrated as having specific components or steps, the embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments. Further, unless otherwise specified, the steps may be performed in any order.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. Thus, the scope of legal protection given to this disclosure can only be determined by studying the following claims.

We claim:

1. A method of detecting a leak in a battery pack, comprising:

calculating a predicted amount of thermal energy at a position;

measuring an actual amount of thermal energy at the position;

moving a fluid through the battery pack using a fan as a fluid movement device: and

comparing the predicted amount to the actual amount to identify if a battery pack is leaking the fluid.

2. The method of claim **1**, wherein the fluid enters the battery pack at an inlet and exits the battery pack at an outlet, the fluid movement device positioned downstream from the inlet and upstream from the outlet relative to a direction of flow through the battery pack.

3. The method of claim **1**, wherein the leaking comprises movement of fluid to the battery pack through areas other than an inlet where the fluid enters the battery pack, movement of fluid from the battery pack through areas other than an outlet where fluid exits the battery pack, or both.

4. The method of claim **1**, further comprising measuring an thermal energy of fluid entering through an inlet to provide an inlet fluid amount of thermal energy, comparing the inlet fluid amount to the predicted amount to identify a location of the leaking.

5. The method of claim **4** further comprising calculating that the leak is between the inlet and the fluid movement device if the inlet fluid amount of thermal energy is greater than the actual amount of thermal energy at the position.

6. The method of claim **1**, wherein the position is at a battery cell of the battery pack.

7. The method of claim **1**, wherein the position is within the battery pack.

8. The method of claim **1**, further comprising identifying a leak when the actual amount is greater than the predicted amount by at least an established threshold value.

9. The method of claim **1**, further comprising identifying a leak when the predicted amount is greater than the actual amount by at least an established threshold value.

10. The method of claim **1**, further comprising measuring the actual amount of thermal energy using a sensor positioned at or adjacent to battery cell of the battery pack.

11. A leak detection assembly for a battery pack, comprising: a sensor to determine an actual amount of thermal energy at an a position; and a fluid movement device to move gas from an inlet to an outlet of the battery pack: and

a controller to calculate a predicted amount of thermal energy at the position, and to indicate that a battery pack includes a leak of the fluid based on a comparison of the predicted amount to the actual amount.

12. The leak detection assembly of claim **11**, wherein the fluid movement device comprises a fan.

13. The leak detection assembly of claim **12**, further comprising a battery pack housing holding a first plurality of battery cells, a second plurality of battery cells, and the fan, wherein the fan is located downstream from the first plurality of battery cells and upstream from the second plurality of battery cells relative to a general direction of flow of the fluid from the inlet to the outlet.

14. The leak detection assembly of claim **11**, wherein the leak comprises movement of fluid to the battery pack through areas other than the inlet, movement of fluid from the battery pack through areas other than the outlet, or both.

15. The leak detection assembly of claim **12**, further comprising an inlet sensor to measure an amount of thermal energy in fluid entering the battery pack through the inlet, wherein the controller is configured to compare the inlet fluid amount to the predicted amount to identify a location of the leaking.

16. The leak detection assembly of claim **12**, wherein the controller indicates the leak when the predicted amount is greater than the actual amount by at least an established threshold value.

17. The leak detection assembly of claim **12**, wherein the controller indicates the leak when the actual amount is greater than the predicted amount by at least an established threshold value.

18. The leak detection assembly of claim **12**, wherein the position is within the battery pack.

19. The leak detection assembly of claim **12**, wherein the position is at or adjacent to a battery cell of the battery pack.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,448,131 B2
APPLICATION NO. : 14/010971
DATED : September 20, 2016
INVENTOR(S) : Xiaoguang Chang et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS:

In claim 15, column 9, line 18; delete "12" and replace with --11--

In claim 16, column 10, line 5; delete "12" and replace with --11--

In claim 17, column 10, line 9; delete "12" and replace with --11--

In claim 18, column 10, line 13; delete "12" and replace with --11--

In claim 19, column 10, line 15; delete "12" and replace with --11--

Signed and Sealed this
Twenty-ninth Day of November, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office